ANALYZING THE CRITICAL ROLE OF SKETCHES IN THE VISUAL TRANSFORMATION OF ARCHITECTURAL DESIGN

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Abstract
Through sketches, designers can seek and create more desirable and sustainable forms by transforming previous images through various techniques like visual additions, deletion, and modifications. Transformative skills in the form of freehand sketches appear to induce creative, explorative, open-ended environments that are conductive in dealing with the ill-structured nature of design activities. This study compares sketching and design transformative skills (DTS) between 3rd and 5th year architectural students as measured throughout the discernible levels of diagrammatic, preliminary, refinement, and detail designing. Fourteen architecture students from the University Technology Malaysia (UTM) were observed, with seven respondents each from the third and fifth year student cohorts. The objective of the observation was to capture and analyze the students’ sketches as they design a gallery within the stipulated two-hour period. The research instrument included a set including an HD video camera, drawing instruments, and a brief outline of the design tasks. The Mann-Whitney test was used to determine if there were differences in design transformation activities between third and fifth year students throughout the period of observation. The results reveal significant differences in vertical move transformation between third and fifth year students within the preliminary, refinement, and detail phases of designing.

Keywords: Sketching; design transformation skills; design expertise

INTRODUCTION
Freehand sketching is helpful for designers because of imagining and recognising many drawing alternatives. Sketch has the crucial role of supporting the mind in converting descriptive information into depiction. Fish (1996) mentions that sketch aids artist to think and support short-term memory. Sketch aids designers in considering problems and is a beneficial technique for communicating ideas to others (Myers et al, 2008). Some of the research in design recognizes that sketching is an effective instrument for conceptual designing. In addition, it can serve as a storage solution as external memory and appear to be important in understanding conflicts and possibilities (Akin, 1978). Therefore, sketching has an important role in design training and it can be beneficial for design development and design creativity.

Transformation is the mechanism that shows the way new designs are generated from unambiguous representations and the prevailing products. Moreover, this is the design that seeks to create desirable and sustainable changes in form (Tovey, Porter, and Newman, 2003). In order to transform descriptions into depictions, the designer employs a set of quick sketches. In this manner, images are generated in mind by sketches, by which the embodied themes in the design are developed. Sequentially, this directs the designer to transform the former image through additions, deletions, and modifications (Tovey et al, 2003). Indeed, transformation moves from unstructured drawing to further detailed and precise illustrated representations.
This study uses retrospective protocol analysis to compare design transformation in four levels of detailing: diagrammatic, preliminary, refinement, and detail designing between third and fifth year students. The contribution of this study is to aid in understanding the difference of design transformation between two levels of design expertise. It is expected that this study will be beneficial for design education and design learning.

**LITERATURE REVIEW**

Transformation is the capability of pattern modification in images and is significant in design generation. This transformation occurs in different context, which will be explained later as a decomposing process. Sketching manipulation takes place for transforming image, situation, and drawing types that result in evaluating design solution (Do et al, 2000).

**Transformation**

Design transformation is the progression from unstructured form to structured form which occurs for creating, modifying, and developing design elements and the design idea. Goel (1995) argued that design is the process from ill-defined problems to the well-defined design problems. It consists of some moves that start from the preliminary phase (unstructured sketch) and the refinement phase of design to detail design (explicit and precise design). Goel (1994) stated that lateral and vertical is transformation, whereas duplication is repeating. A lateral transformation is identified as “movement… from one idea to a slightly different idea”. They are essential for broadening the problem space and the assessment and improvement of kernel ideas. A vertical transformation is identified as “movement… from one idea to a more detailed version of the same idea”. It causes the problem space to deepen. Lateral transformations mostly take place in the initial design stages and are related to unstructured drawing while vertical transformations take place throughout the refinement and detailed design stages and are related to more precise and detailed design.

Van der Lugt (2000) investigated features of design transformation that occur in idea links. He defined ideas as three subclasses in a link: supplementary, modification, and tangential links. The supplementary link shows auxiliary and small change on the same version of the idea; the modification link relates to changes in the structure of ideas, however keeping the current line of thought; the tangential link indicates a radical and fundamental change from the earlier idea. He describes that a higher tangential link showed that design ideas have rich novelty whereas a higher supplementary link and modification link indicated development in the idea. Van der Lugt (2000) also mentioned that a creative process consists of a balance among link types. Similarly, Rodgers, Green, and McGown (2000) mention that the balance between vertical and lateral transformation results in good design.

Abdelmohsen and Do (2007) investigate the concept development of two Ph.D. students that had two and six years of professional experience. They evaluate the development of the concept based on vertical and lateral transformation in three seasons: creating design options in schematic design, developing and refining design options, and detailing the revised design. A protocol analysis was used for studying concept development in the schematic and refined stages of design. Moreover, they decompose the design process to three meaningful strokes, namely: transferred, blocked, or added. Abdelmohsen and Do (2007) extended the notion of design transformation by defining processes described as vertical promotion and lateral promotion and cross propagation. Indeed, they evaluate design transformation by meaningful strokes in the macro level.

**Differences between two levels of design expertise**
Different studies have emerged that offer contradictory finding about differences in design expertise. Suwa and Tversky (1997) compare the design thoughts of two groups, advanced students and practicing architects, during the sketching of a museum. A retrospective protocol analysis was considered for this issue. The authors observed that the whole process of design consisted of two groups of segments, the alone segment which they named the isolated segment and the contiguous segment which is set in one block that the authors named the dependency chunk. The isolated segment and the initial segment of the dependency block shows that designers focus on previous thought and shift to an alternative topic, item, or space. Suwa and Tversky (1997) name these segments by means of focus-shift that corresponds to lateral transformation; in addition, with the exception of the initial segment, they name further segments located in the dependency chunk as continuing segments that relate to vertical transformation. The authors concluded that practicing architects used dependency chunk longer and more than advanced students.

Kavakli and Gero (2001) investigated the cognitive processes of novice and expert designers in which the expert designers produced 7 alternatives whereas the novice students had 2, thus they conclude that alternative interpretations’ perception and spatial relations’ organization may consume more time for the novice than expert designers (Kavakli and Gero, 2001). They described that the main difference in their sketches is that there was more intensity in the representation of design ideas as seen in the expert’s design alternatives (Kavakli and Gero, 2001). Moreover, Atman et al (2005) gathered verbal protocols from first year engineering students (freshman) with fourth year engineering students (senior) while they worked on two design problems. They define that, in contrast to the senior students, freshmen considered less alternative solutions, gathered less information, and transitioned less frequently between types of design activities. By comparing literature, it is obvious that the “expert is more productive than the novice” based on the quantities of alternatives and pages created; practicing architects utilized vertical transformation more and longer than advanced students.

Sketch
In the primary phase of the design process, sketch has a crucial role among the traditional mediums and is the elementary depictive action that is performed by designers during the design process. Garner (1990) mentions that sketching fundamentally affects the development, creation, evaluation, and distribution of ideas. Moreover, Goel (1995) suggests that being “syntactically” and “semantically” unclear and ambiguous, the sketches influence the heuristic, creative, open-ended stage of problem-solving. Some researchers like Fish and Scrivener (1990), Goel (1995), and Goldschmidt (1991) came to the conclusion that rough and untidy sketching allows the designer to work quickly, suspending judgment on polished features. Moreover, it could help in generating new ideas. Purcell and Gero (1998) state that in design perception research, a considerable number of studies have focused on the roles of sketches in the conceptual design process and their relationship to designer’s cognition. Indeed, for simplifying the existing ideas and developing new ones, sketching can be helpful.

Decomposing Process
Several attempts have been made to decompose the whole design process into three different components for analysing and measuring it: context, chunk, and move (Figure 1).
Figure 1. Decomposing design process to context, chunk, and move

Context

The designers change their focus in design and refine the domain knowledge by the context of sketch (Cai, Do, and Zimring, 2010). Gross and Do (1996) argue a similar drawing symbol might have a different sense in a different context. Do et al. (2000) stated that transformation can occur in design and context through manipulating shape and changing drawing types and viewpoints. Previous studies have classified context in the design process based on design development, the level of abstraction, and presentation types.

The first type of context is classified based on design development, Goel (1994, 1995, and 2014) categorized the development of design into the four subcategories: (1) problem-structuring, which arranges the problem, (2) preliminary-design, which creates some solution options and idea cores, (3) refinement-design, which improves the current sketch by transformation, and (4) detail-design, which presents the design product. Similarly, Abdelmohsen and Do (2007) classified seasons of design into three phases. In the first phase, several solution options are created in schematic plan drawings. In the second phase, designers refine and improve options. In the third phase, they improve refined drawing to the product of design and organization elements (Table 1). Although diagram has an important role in design thinking and sketching types, design development of Goel do not include diagrams. For Goel, diagrams are more related to function, whereas preliminary design is related to form conceptual design. It seems that it may however be more useful to add diagram to design development.

The second type of context is the abstraction level. Designers use abstract diagrams and unstructured forms in early phases of the design process, while they utilize detailed and structured representations in later phases of the design process (Purcell and Gero, 1998). Fish and Scrivener (1990) categorize the element of pictorial representation from description to spatial depiction and argue that sketch has an essential role in supporting the mind by interpreting the “descriptive propositional information” to depiction. Goel (1995) in “Sketch of Thought” mentioned that the design process contains some movement from ambiguity and vague shape, which is important in the early phase of design to more structure form in detailed design. Consequently, this is a process of developing from unclear sketch to detailed form; he notes that the design transformation process moves from abstraction level to convention document. He (1995) describes drawings as “external symbol systems for representing the real world artifacts”. He (1995) familiarizes some drawing from graphic thinking of Laseau (2001) and classifies them as the symbolic system. Goel (1995) lists them as bubble diagram, layout diagram, conceptual sketch, first sketch of floor plan, schematic of floor plan, quick freehand perspective and some detail. Cai et al. (2010) classified stimuli for inspiration sources regarding levels of abstraction demonstrated different contexts. These stimuli are adapted from “Frank Lloyd Wright’s Robie
House”. They categorize these stimuli as “keyword, diagram, plan, sketch rendering, and precedent photo” (Table 1).

Last, the third type of context is presentation. Do et al (2000) and Bar-Eli (2013) pointed out several types of projection (presentation types) like elevation, plan, elevation, section, and perspective (Table 1).

<table>
<thead>
<tr>
<th>Table 1. Three different context in design process</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Context</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Abstraction level</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Presentation types</td>
</tr>
</tbody>
</table>

**Chunk**
Goldschmidt (1992) recognized that chunk consists of some moves and the relationships between them. She defined chunk as “the block of links among successive moves that link exclusively among themselves and [are] barely interconnected with other moves”. Goldschmidt (1992) restricts chunk according to design moves with the large number, whereas Suwa and Tversky (1997) structured them based on segments with the smaller number. Chunk is often used in linkography, as opposed to other methods.

**Move**
Goldschmidt (1990) decomposes the design process into small parts of “design moves” by using linkography. Goldschmidt defined a movement as “a step, an act, an operation, which transforms the design situation relative to the state in which it was prior to that move” (Goldschmidt, 1995b) or can be separate as “the smallest coherent operation detectable in design activity” (Goldschmidt, 1992). Goldschmidt (1995a) mentions that considering design move can result in analyzing and assessing the design process. Moreover, Goel (1995) defined three design movements: vertical and lateral, which are transforming, and duplication, which is repeating. It seems that design development of Goel is more relevant to design transformation and idea development. However, diagram plays an essential role in design thinking and the lack of diagram in the previous classification of levels of detailing can be seen. Therefore, the current study improves the design...
development model of Goel (1994) as design transformation model and categorizes it based on four levels of detailing namely, diagram, preliminary design, refinement design, and detail design. The current study aims to measure design transformation based on movements in levels of detailing (design development).

METHOD

Data Gathering
Most design researchers used protocol analysis to measure cognitive activity that take place in designing and the process of design. The protocol was divided into two subclasses: concurrent protocols and retrospective protocols (Ericsson and Simon, 1993). Concurrent protocols are obtained from the explanation of a designer’s thinking during their sketching. Retrospective protocols are obtained from the explanation of a designer’s thinking after they completed their sketching. Design researchers used two types of protocol based on the nature of the problem in research design. Process-oriented design studies associated with concurrent protocols, whereas content-oriented design studies related to retrospective protocols (Dorst and Dijkhuis, 1995). Design researchers did not find any research methodology that was suitable for different goals and diverse situations (Goldschmidt and Weil, 1998). The think-aloud protocol is not used in this study because previous studies suggested that talking aloud concurrently may limit the perception of the participant during their drawing activities (Ericsson and Simon, 1993). This effect may be a weakness in our study since our aim was to investigate transformation difference between two groups. We interviewed the participants after they finished their design task as a retrospective protocol. We interviewed 14 undergraduate architecture students of the University of Technology Malaysia in separate individual design activities. All of the students worked on designing a gallery of seashell and stone.

Segment
Previous design researchers decomposed the verbal protocol into small parts as segmentation. Segmentation is defined according to different events. The first is verbalization actions such as intonations, pauses, and syntactic signs for complete sentences and phrases (Ericsson and Simon, 1993; Gero and Mc Neill, 1998; Goldschmidt, 1991). The second is defined according to the “subject’s intention” (Goldschmidt, 1991; Suwa and Tversky, 1997). For instance, Goldschmidt (1991) determined a segment as design move, which is defined as “an act of reasoning which presents a coherent proposition pertaining to an entity that is being designed”. A change in the designer’s thought contents, their action, and their intention in a subject for the sign for the start and the end of the new segment. Therefore, one segment sometimes contains many sentences and sometimes only one. Moreover, Chiu (2003) analyzes design activities of designers in equal time sequence. We use the latter approach, which means that segmentation in the current study employed equal segments for measuring design transformation in ordinal scale. Since two movements have different time periods, this study divided design process into 30-second equal segments. By considering equal segments, we can measure design transformation more exactly in ordinal scale. It means that one movement can consist of one segment or more than one segment.

Coding
In design studies, coding schemes are needed for defining different action categories in protocol analysis. There are a variety of developed coding schemes depending on the purpose and the scope of every study. The retrospective protocol analysis method applied in this study is based on a content-oriented approach. This section proposes a unique method for tabulating transformation activities. It follows earlier suggestions that each complete segment is encoded with relevant attributes (in bracket) under the following three categories: (1) transformation type
(lateral or vertical), (2) presentation types (ground floor, first floor, section, elevation, and perspective), and (3) levels of detailing (diagram, preliminary design, refinement design, and detail design). These attributes then populate a table referred to as the matrix of design transformation. The tables were created using Microsoft Excel. The following sections highlight the basis for the current tabulation format (Table 2).

Table 2. Sub codes of presentation types, transformation types and levels of detailing in DTM

<table>
<thead>
<tr>
<th>PRESENTATION TYPES</th>
<th>TRANSFORMATION TYPES</th>
<th>PHASES OF DETAILING</th>
</tr>
</thead>
<tbody>
<tr>
<td>GF: Ground floor</td>
<td>V: Vertical</td>
<td>DI: Diagram</td>
</tr>
<tr>
<td>FF: First floor</td>
<td>L: Lateral</td>
<td>PR: Preliminary design</td>
</tr>
<tr>
<td>SE: Section</td>
<td>0: No movement</td>
<td>RE: Refinement design</td>
</tr>
<tr>
<td>El: Elevation</td>
<td>O.M: Another movement that is not transformation like duplication</td>
<td>DE: Detailing design</td>
</tr>
<tr>
<td>PE: Perspective</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Design Transformation**

As mentioned before, Goel (1995) used the term transformation in describing the movements of ideas: a lateral transformation indicates a “shift from one idea to a different idea”, while vertical transformation suggests a detailed development of the same idea.

**Levels of Detailing**

This study updates the design development model of (Goel, 1994) as a design transformation model and categorizes it based on four levels of detailing namely, diagram, preliminary design, refinement design, and detail design. In the diagrammatic phase of the design process, designers evaluate functions, position, and relationships between spaces as in a bubble diagram. That is consistent with unstructured drawing and abstract schematic. In the preliminary phase of the design process, designers try to generate shape, concept, and kernel ideas. They keep alternatives open and prospects broad. That is the early effort to produce shape. In refinement design, designers develop and revise kernel idea or early generated design idea. In detailing design, designers take the final shape of the form of the idea that consists of precise and structured forms of dimensioned drawing and straight line (Table 3).

**Design Protocol Measurement**

Khaidzir and Lawson (2013) propose a Cognitive Interaction Matrix (CIM) framework for examining the intricate nature of design studio interactions. CIM illustrates encoded cognitive segments for each design tutorial meeting recorded for the aim of the study. The CIM multi-coding framework offers an inclusive and systematic cognitive description for each protocol segment. This study uses a multi-coding matrix in a different content, as a design transformation matrix (DTM) to code and insert data. This matrix converts qualitative data to quantitative data (Table 4).

Table 3. New model of design transformation in levels of detailing based on Goel’s framework (Goel, 1994).
Table 4. Design transformation matrix (DTM), organized based on the equal segment.

<table>
<thead>
<tr>
<th>Segment No</th>
<th>Time Duration</th>
<th>Sheet</th>
<th>Presentation Types</th>
<th>Transformation Types</th>
<th>Phases Of Detailing</th>
</tr>
</thead>
<tbody>
<tr>
<td>59</td>
<td>0:29:00</td>
<td>5</td>
<td>GF</td>
<td>L</td>
<td>PR</td>
</tr>
<tr>
<td>60</td>
<td>0:29:30</td>
<td>5</td>
<td>GF</td>
<td>L</td>
<td>PR</td>
</tr>
<tr>
<td>61</td>
<td>0:30:00</td>
<td>5</td>
<td>GF</td>
<td>L</td>
<td>PR</td>
</tr>
<tr>
<td>62</td>
<td>0:30:30</td>
<td>5</td>
<td>GF</td>
<td>L</td>
<td>PR</td>
</tr>
<tr>
<td>63</td>
<td>0:31:00</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>64</td>
<td>0:31:30</td>
<td>5</td>
<td>GF</td>
<td>L</td>
<td>PR</td>
</tr>
<tr>
<td>65</td>
<td>0:32:00</td>
<td>5</td>
<td>GF</td>
<td>V</td>
<td>PR</td>
</tr>
<tr>
<td>66</td>
<td>0:32:30</td>
<td>5</td>
<td>GF</td>
<td>V</td>
<td>PR</td>
</tr>
<tr>
<td>67</td>
<td>0:33:00</td>
<td>5</td>
<td>GF</td>
<td>O-M</td>
<td>PR</td>
</tr>
<tr>
<td>68</td>
<td>0:33:30</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>69</td>
<td>0:34:00</td>
<td>5</td>
<td>GF</td>
<td>V</td>
<td>PR</td>
</tr>
<tr>
<td>70</td>
<td>0:34:30</td>
<td>5</td>
<td>GF</td>
<td>V</td>
<td>PR</td>
</tr>
</tbody>
</table>

Scope
The University of Technology Malaysia has two architecture programmes for undergraduate architecture students, the old one is five years, and the new one is three years. This study compares undergraduate students in the two groups. As such, 14 undergraduate architecture students at the university technology Malaysia (UTM) are involved in this experiment, 7 third and 7 fifth year students. They were asked to complete a design task in two hours. The research instruments include a video camera, a set of drawing tools, and the design task.

Analysis
All statistics are analyzed using the Mann-Whitney U-tests (Clark-Carter, 1997) through SPSS statistical analysis software. Mann-Whitney U-tests are used to test the differences between two independent samples. (Mann-Whitney U is the non-parametric equivalent of a t-test and compares the ranked scores of the two groups).

FINDINGS AND DISCUSSION

In this part, the null hypothesis is that the period of transformation of both groups is equal in four levels of detailing, so if the result is significant, the null hypothesis is rejected. The Wilcoxon-Mann-Whitney test was applied on the ranked using the period of transformation between third and fifth year students. Table 5 shows the periods of transformation that were produced by third and fifth year students. For this experiment, the Wilcoxon-Mann-Whitney test was chosen to establish if third and fifth years students hold similar (null hypothesis) or different (alternative hypothesis) statistical distribution in design transformation. It can be seen from the table, in the diagrammatic phase of detailing, the vertical (P=0.40) and lateral (P=0.72) p-values were beyond the 0.05 level. Therefore, the Mann-Whitney test failed to establish significance beyond the 0.05 level in the difference of transformation between two groups in the diagram. In preliminary and detail design, the p-values are 0.015 and 0.034 respectively. This indicates that third year students spend more time for vertical transformation in these two levels of detailing.

On the other hand, fifth year students use vertical and lateral more than third year students in refinement design; this is indicated by p-values below 0.05, and the significance of vertical and lateral is 0.015 and 0.045 respectively. Thus, although third year students have more activity in idea development in preliminary and detail design, fifth year students spend more time during idea development and modification of their idea in refinement design.

Table 5. Significant of design transformation difference in 4 levels of detailing

<table>
<thead>
<tr>
<th>Levels Of Detailing</th>
<th>Transformation</th>
<th>Significant</th>
<th>Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>3th Years</td>
</tr>
<tr>
<td>Diagram</td>
<td>Vertical</td>
<td>0.40</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>0.72</td>
<td>50</td>
</tr>
<tr>
<td>Preliminary Design</td>
<td>Vertical</td>
<td>0.015</td>
<td>71.5</td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>0.14</td>
<td>64</td>
</tr>
<tr>
<td>Refinement Design</td>
<td>Vertical</td>
<td>0.015</td>
<td>33.5</td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>0.045</td>
<td>37.5</td>
</tr>
<tr>
<td>Detail design</td>
<td>Vertical</td>
<td>0.034</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>Lateral</td>
<td>0.21</td>
<td>43</td>
</tr>
</tbody>
</table>

CONCLUSION

The aim of this study was to evaluate differences in design transformation between third and fifth-year undergraduate students in 4 levels of detailing. Findings indicate some significant difference of transformation between the two groups. By considering time segments, it is obvious that third-year student use vertical transformation longer than fifth years in preliminary design and detail design, while the third year students utilize vertical and lateral for less time than fifth year students in refinement design. Thus, third year students spend more time generating each alternative solution and kernel idea than do fifth year students in preliminary design. On the other hand, fifth year students utilize vertical (convergence thinking) and lateral (divergence thinking) more than third year students in refinement design. In other words, fifth year students develop in-
depth and revise kernel ideas more in this phase. Finally in the detailing phase, third year students develop their idea more than fifth year students. Therefore, fifth year students fix their design in refinement design more than third year students. This finding indicates how students use different Design Transformation Skills (DTS) among levels of design detailing. The results of this study are expected to be beneficial for the distinction of design expertise levels. We plan to compare further the result of equal segments (ordinal scale) with real time (ratio scale) to understand differences between them.

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